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## High Speed Rail, megalopolis and house prices: what is the link?

Francesca Pagliara<sup>a</sup>

<sup>a</sup> Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II, Via Claudio 21, 80125 Naples, Italy

### Abstract

In the recent years High Speed Rail (HSR) systems deployment has changed users' travel behaviour together with their life style thanks to their power of shrinking spaces. Investments in HSR systems are not only motivated by an increase in transport infrastructure capacity and their being environmentally friendly, but also by the fact that they promote economic growth and regional development. Indeed the objective of this paper is to build a framework for understanding and exploring the relationships between the phenomenon of megalopolis formation and HSR and determine the possibility and magnitude of associated impacts on house prices.

The original contribution of this paper is represented by the specification of a model which aims to explain the mechanisms through which metro areas integrate into megalopolises and to understand what is the role of HSR systems in this respect. Generalized linear models (GLMs) are here considered the most suitable ones in order to model the phenomenon under analysis. The dependent variables are represented by the changes in house prices between the cities connected by the HSR link, while as dependent variables several socio-economic indicators have been considered as well transport related variables, such as HSR travel time, HSR travel cost, HSR frequency, etc.

Three HSR corridors in Italy have been chosen as case studies, i.e. MITO (Milano-Torino, in the north), BOFIRO (BOlogna-FIrenze-ROMa in the centre) and RONA (ROMa-NAPoli in the south) having the potential for megalopolises formation as supported by HSR. Model estimation provides interesting results. Specifically, the main conclusion is that Milano and Torino are two independent cities and that the HSR link connecting the two cities has not an impact on the formation of the MITO megalopolis. The same result for the cities of Bologna, Firenze and Roma, while for the case study of the RONA it seems that a megalopolis exists between the two having also an impact on house prices change.

**Keywords:** High Speed Rail; Megalopolis formation; house prices change

### 1. Introduction

In the recent years, many countries of the world have been investing in High Speed Rail (HSR) systems since, with respect to the other alternative transport modes, they represent an optimal solution to meet challenges of increasing mobility demand, while simultaneously addressing the greater attention of citizens to sustainability issues (Melibaeva *et al.*, 2010; Pagliara *et al.*, 2011).

The implementation of HSR lines plays an important role in reshaping the travel patterns and activities of people and consequently changing the ways cities develop.

Indeed HSR system for many countries has also fostered the promotion of economic growth and regional development. The potential for megalopolis formation, i.e. an integrated economic urban complex created by fusion of multiple cities connected at high-speed of 200-300 km/h, is the focus of this contribution. Megalopolises can have many positive economic impacts stemming from larger labor markets, larger commercial markets, expanded individual daily activity zones, etc. (Sussman, 2011).

In this paper, a framework for understanding and exploring the relationships between the phenomenon of megalopolis formation and High Speed Rail deployment is proposed. The objective is to determine the possibility and magnitude of associated impacts on regional development. The original contribution lies in the specification of a theoretical model which aims to explain the mechanisms through which metro areas integrate into megalopolises and to understand what the role of HSR systems is. Three case studies have been analysed the MITO (Milano-TORino), BOFIRO (BOlogna-FIrenze-ROma) and RONA (ROma-NApoli) megalopolises in Italy.

HSR can change the geography of a country, bringing regions and cities closer to each other by increasing accessibility. These benefits in turn can be the basis for promoting economic development, justifying the higher costs of HSR investments.

In the contribution by Kobayashi and Okumura (1997) they propose a dynamic multi-regional growth model which simulates the dynamic processes of economic development of city systems. The economic system consists of multiple cities interconnected by HSR systems with each city consisting of one production sector as well as residential land use. The railway systems provide production sectors of different cities with the opportunity of face-to-face communication for knowledge production. The model emphasize how differences in geographic and qualitative factors of high-speed railway systems may affect regional economic development.

In the paper by Perl and Goetz (2015) three models of HSR development are identified: (1) exclusive corridors (e.g. Japan), (2) hybrid networks-both national (e.g. France and Germany) and international (e.g. European Union), and (3) comprehensive national networks (e.g. China and Spain). In its original model, HSR systems are conceived to serve corridors of 480-560km connecting two megacities. The second model of HSR was introduced as a "hybrid system that blended high speed travel across new dedicated trunk line infrastructure together with operation at conventional speeds along interconnected branch lines shared with regular trains". This hybrid strategy multiplied the number of origins and destinations that could be served by HSR. The third model of HSR linked major cities and mid-sized communities across countries such as China and Spain. In China, a four east-west and four north-south HSR lines connect many large cities, covering routes up to 1600 km long.

The paper by Ureña *et al.* (2009) proposes big intermediate cities along HSR lines, and examines HSR's capacity to change time distances and accessibility. Indeed the role of HSR in promoting new opportunities for Cordoba and Zaragoza in Spain and Lille in France is highlighted. The introduction of regional HSR services transform the connections and the time distances from some of the small cities to the metropolitan areas and to the big intermediate cities. In this contribution it is clear the power of HSR in changing balance and hierarchy of the established city system, by improving the regional centrality of big intermediate cities with respect to given smaller regional cities.

Due to the trends of urbanization and motorization in India, an urgent need is present for integration, revitalization and renewal of the smaller towns and cities to make urban areas in this country more sustainable. Indeed the urbanization process is becoming unsustainable. Local government asserts that a solution can be found in providing opportunities for medium and smaller size cities through their integrations and it argued that HSR can play a significant role in achieving this. "A more balanced and sustainable development of towns and cities, opening up opportunities for growth across a wider, interconnected, region, with the benefit of taking the pressure of the larger cities to absorb additional burgeoning populations" Verma *et al.* (2013).

The paper by Zheng and Kahn (2013) supports the claim that China's bullet trains are playing a significant role in China facing the question of growing megacities suffering from different problems. Indeed high levels of traffic congestion, pollution, are the main causes for degrading the quality of life. Transportation technology, allowing individuals to access the megacity without living within its boundaries, provides large benefits, since people could enjoy the advantages of urban agglomeration, without paying megacity real estate rents and city's social costs.

Since 2007 China has introduced bullet trains connecting megacities such as Beijing, Shanghai, and Guangzhou with nearby cities. Through facilitating market integration, bullet trains can stimulate the development of second and third-tier cities and they can help protecting the quality of life of the growing urban population.

Another contribution from China (Yang *et al.*, 2011) presents the trends in mobility in China's three megaregions, i.e. the Capital Economic Zone, the Yangtze River Delta and the Pearl River Delta- and how megaregional development has led to solutions to the challenges of mobility. It is highlighted that the development of megacity regions is the most important spatial strategy carried out in recent years in China. The Yangzi-Delta Regional Plan is a good example since it aims at strengthening the development of the core city of Shanghai, increase the attractiveness of medium cities like Nanjing, Hangzhou, Suzhou, Ningbo and other smaller centres, and encourage the different cities to develop different, yet complementary economic functions and become part of a more integrated region. The inter-city HSR network can be supportive of this strategy. This experience has been compared with trends in megaregions in USA and in Europe. This comparison has confirmed that China's investments into rail, and particularly HSR, has provided a better chance to reduce congestion and pollution.

The paper by Ross (2011), for the case study of the USA, suggests that HSR is an attractive transport alternative to consider in providing greater connectivity between and within megaregions. The latter "offer an appropriate spatial scale for US rail planning". For the United Nations urbanisation is now becoming unbearable and therefore new challenges are requested to transportation systems. "The role of technology, the demands for more sustainable mobility systems, the demand for clean energy sources more friendly to the environment, emerging megaregions and markets all suggest a need for new, improved and more efficient mobility systems". A number of states and regions and the federal government have promoted the development of a national HSR system in the United States. These projects foster the competitiveness of the megaregions in which they are placed.

The paper by Ross and Woo (2012) analyses the proposed HSR programs by the U.S. Department of Transportation's Federal Railroad Administration and finds that most HSR routes with higher investment priority are located within megaregions and across state boundaries and that the recently released federal HSR programs are moving to take the multijurisdictional interactions into account for allocating HSR funds. The results imply that the megaregion would be an appropriate scale for developing HSR in terms of the benefits and effectiveness of implementation.

Interesting are the contributions provided in the literature on time-space maps, which represent the interaction between space and time cartographically. In time-space maps the distance between two points is not proportional to their physical distance (as in physical maps) but proportional to the travel time between them. This change of map scale leads to distortions of the map compared with "familiar" physical maps.

The concept of time-space convergence has been introduced to show that larger cities benefited more than smaller cities from the contraction of time-space by faster transport means (Janelle 1968; Janelle and Gillespie, 2004). For Janelle (1968) the modernisation of transport systems is seen as a factor of concentration in urban agglomerations and he demonstrates that the increase in speed delivers stronger effect on time-space contraction on long distances than on short distance (L'Hostis, 2009). The evolution of the system of speeds gives an advantage to the larger cities over smaller ones.

In the paper by L'Hostis (2009) it is clearly stated that "*understanding distances between places is a fundamental task for the geographer, while the representation of distances constitutes one of the major functions of cartography*".

The rest of the paper is organised as follows. In section 2 the case studies of MITO, BOFIRO and RONA megalopolises are described. Section 3 deals with the theoretical model proposed and the calibration results. Conclusions and policy implications are reported in section 4.

## 2. The MITO, RONA and BOFIRO Megalopolises

In Italy, the first HSR line was inaugurated in 1992 between Florence and Rome with the so called "Direttissima", which allowed trains to run at 230 km/h covering the 254 km between Rome and Florence in about two hours. However, this project dated back to 1970.

The new generation of HSR (i.e. with trains running at 300 km/h) started in December 2005 between Rome and Naples and Milan and Bologna. Later, in December 2009, the project was extended with the Milan-Turin and the Bologna-Florence lines, as well as with the urban penetration into the cities of Rome and Naples. In 2015 the Italian HSR network was operational for more than 1400 km (see Figure 1).

The national Italian network and operations are all owned by FS (State Railway) Holdings, a fully government owned company. It has three key operating subsidiaries: Trenitalia operates all freight and passenger trains, including the high-speed trains, RFI (Rete Ferroviaria Italiana) manages the infrastructure, and TAV (Treno Alta Velocità SpA) is responsible for the planning and construction of the new HS infrastructure.

The introduction of the new private operator Nuovo Trasporto Viaggiatori (NTV) in April 2012, competing with the Trenitalia on the national HSR network, represents the first case of competing HSRs operating on the same line (i.e. multiple operators on a single infrastructure). NTV represents the first private society to benefit of the European liberalisation of the HS train networks.

The High Speed/High Capacity (HS/HC) system in Italy is called "the Italian metro" connecting only big metropolitan cities. The system is also a High Capacity one since some lines are not new ones, but they have been renewed by increasing train frequencies.



Source: Delaplace *et al.* (2014)

Figure 1. The High Speed/High Capacity Rail network in Italy

In July 2009 Milan was connected by a HSR link to Turin, the line is 148,3km long. Roma and Napoli were connected as a result of the inauguration of the HSR link between the two cities of 204,6km long in December 2005. In 2009 the HSR corridor BOFI (Bologna-Firenze - 92Km) was inaugurated, while in 1992 the HSR corridor FIRO (Firenze-ROMa - 253,6Km) became operational. The total length of the HSR corridor BOFIRO is 345,6Km.

### 3. The methodology

The methodology proposes variables as count data, consisting of non-negative integer values. A common mistake is to model count data as continuous data by applying standard least squares regressions (Washington *et al.*, 2010). Generalized linear models (GLMs) are here considered the most suitable ones in order to determine the relationship between count data and tourism and transport variables. GLMs aim at extending ordinary regression models to encompass non-normal response distributions. Common GLMs include linear regressions, logistic regressions and Poisson regressions (Agresti, 2002). In this paper a Poisson regression specification has been considered. The density function of the dependent variable  $Y$  has the following form:

$$f(y) = \frac{\lambda^y e^{-\lambda}}{y!} \quad y = 0, 1, 2, \dots, \infty.$$

The mean and the variance are given by  $E[Y] = \lambda$  and  $V[Y] = \lambda$ . The Poisson model has been parameterized in terms of  $\beta x$ . The choice of the variables is based on the contribution of here adapted to the case study under

analysis. The database covers the period 2002-2015. The sources are ISTAT (the Italian census) and data concerning house prices have been provided by Agenzia delle Entrate.

Therefore, the specification of the proposed model follows:

$\Delta HousePrice_t =$

$$\beta_0 + \beta_{Growth-Rate} Growth-Rate_t + \beta_{Res-Dens} Res-Dens_t + \beta_{Migration-Rate} Migration-Rate_t + \beta_{GDP} GDP_t + \beta_{UNEMP-RATE} UNEMP-RATE_t + \beta_{TIME-HSR} TIME-HSR + \beta_{COST-HSR} COST-HSR + \beta_{FREQ-HSR} FREQ-HSR + \beta_{COMF-HSR} COMF-HSR$$

The dependent variable is:

$\Delta HousePrice_t$ : is the house price change between the two cities under analysis for every year  $t$ .

The independent variables are:

*Growth-Rate*: is the weighted average population growth rate (change measured for 1000 inhabitants) equal to:

$$Growth-Rate_t = \frac{Growth-Rate_{At} * Y_{At} + Growth-Rate_{Bt} * Y_{Bt}}{Y_{At} + Y_{Bt}}$$

Where:

$Y_t$  is equal to the population  $POP_t$  or house price  $HousePrice_t$  at year  $t$ .

If the dependent variable is  $\Delta POP_t$ , the variable *Growth-Rate* is weighted with respect to the population. On the other hand, if the dependent variable is  $\Delta HousePrice_t$  the variable *Growth-Rate* is weighted with respect to the house price. The same approach has been applied for the following socioeconomic variables:

*Res-Dens*: is the average residential density between the two cities under analysis for every year  $t$  (no. of inhabitants/km<sup>2</sup>).

*Migration-Rate*: is the difference between the number of immigrants and that of the emigrants referred to a given city for every year  $t$  (change measured for 1000 inhabitants).

*GDP*: is the Gross Domestic Product for each city for every year  $t$ ;

*UNEMP-RATE*: is the unemployment rate for each city for every year  $t$  (measured as a percentage);

*TIME-HSR*: is the HSR travel time expressed in minutes along a given corridor;

*COST-HSR*: is the HSR travel cost expressed in Euros along a given corridor;

*FREQ-HSR*: is the HSR frequency expressed in number of runs along a given corridor;

*COMF-HSR*: is the HSR comfort, which is a dummy variable equal to 0 before the inauguration of the HSR line between the two cities and 1 after the inauguration.

In Table 1 estimation results are reported for the HSR MITO corridor but w.r.t.  $\Delta HousePrice$ . The latter is influenced by the socioeconomic variables *Growth-Rate*, *Res-Dens* and *GDP*, which are positive and significant, having therefore an impact on house prices change.

Concerning the HSR related variables, the *FREQ-HSR*, *COST-HSR* and *TIME-HSR* are significant and of the expected sign, meaning that the HSR link has brought an increase in accessibility and on house prices as well.

Coefficient							
	$\beta_{Growth-Rate}$	$\beta_{Res-Dens}$	$\beta_{Migration-Rate}$	$\beta_{GDP}$	$\beta_{FREQ-HSR}$	$\beta_{COST-HSR}$	$\beta_{TIME-HSR}$
Value	1.61	0.003	-1.613	0.04	0.201	-2.899	-13.24
t-student	(5.38)	(3.17)	(-5.37)	(3.03)	(4.45)	(-5.3)	(-5.16)
$\rho^2$	0.48						
$\rho^2_{adj}$	0.47						

Source: Authors' elaboration

Table 1. MITO HSR corridor

$\Delta HousePrice$  for the HSR RONA corridor (see Table 2) is influenced by the socioeconomic variables *Res-Dens* and *UNEMP-RATE*, being both significant. The variables *FREQ-HSR*, *COST-HSR* and *TIME-HSR* are all significant and of the expected sign considering that the HSR link between the two cities has also in this case an impact on house prices.

Coefficient					
	$\beta_{Res-Dens}$	$\beta_{UNEMP-RATE}$	$\beta_{FREQ-HSR}$	$\beta_{COST-HSR}$	$\beta_{TIME-HSR}$
Value	0.09	-2.60	0.42	-0.58	-0.15
t-student	(3.74)	(-4.06)	(3.61)	(-2.15)	(-2.10)
$\rho^2$	0.55				
$\rho^2_{adj}$	0.54				

Source: Authors' elaboration

Table 2. RONA HSR corridor

For the BOFIRO HSR corridor, the models have a good ability in reproducing the available data since the  $\rho^2$  value is high, and all the socio-economic variable are significant and of the expected sign. However, the HSR related variables are not present in all the models, since they have been excluded being not significant or not of the expected sign (see Table 3 and 4). The ones that have been left are significant, but this analysis shows that between Bologna, Firenze and Roma a megalopolis does not exist due to HSR.

Coefficient					
	$\beta_{Growth-Rate}$	$\beta_{Migration-Rate}$	$\beta_{UNEMP-RATE}$	$\beta_{GDP}$	$\beta_{TIME-HSR}$

Value	0.366	-0.364	-0.270	0.0025	-0.550
t-student	(2.32)	(-2.37)	(-1.98)	(1.99)	(-2.52)
$\rho^2$	0.49				
$\rho^2_{adj}$	0.485				

Source: Authors' elaboration

Table 3. BOFI HSR corridor

Coefficient					
	$\beta_{Growth-Rate}$	$\beta_{Res-Dens}$	$\beta_{Migration-Rate}$	$\beta_{GDP}$	$\beta_{COST-HSR}$
Value	0.747	-0.005	-0.823	0.02	-0.011
t-student	(3.24)	(-2.50)	(-3.35)	(1.98)	(-2.77)
$\rho^2$	0.56				
$\rho^2_{adj}$	0.55				

Source: Authors' elaboration

Table 4. FIRO HSR corridor

#### 4. Conclusions and further perspectives

HSR investment is associated with potential changes in accessibility, as a result of reduction in travel time, which in turn may lead to economic and functional integration of multiple urban areas with the possibility of fusing them into a megalopolis (Sussman, 2011).

The way that the urban areas are impacted by the new HSR is highly dependent on conditions present in cities also before HS connection (e.g. economy, existing transport links, etc.).

This paper has looked at HSR effects of shrivelling of time-space and consequently of changing mobility patterns and shaping regions. Specifically, it has provided a contribution on the potential effects of HSR in the emergence of megalopolis.

Three case studies in Italy have been considered, i.e. the MITO, BOFIRO and RONA HSR corridors in Italy. Estimation results show that between Milan and Turin, the introduction of the HSR link has not contributed to the formation of the MITO megalopolis. The same for the BOFIRO HSR corridor. On the other hand, it seems that the RONA megalopolis has been shaped thanks to the HSR link between Rome and Naples. Estimation results concerning the HSR related variables confirm this result.

A further analysis has been proposed in order to support the results obtained. In Fig. 2 the variable  $\Delta HousePrice$ , analysed within the time period 2002-2015, for the MITO HSR corridor has been compared with the one of the NON-HSR GEMI (GEnova-Milano) corridor. It is clear that after the year 2009 there is not an increase of the



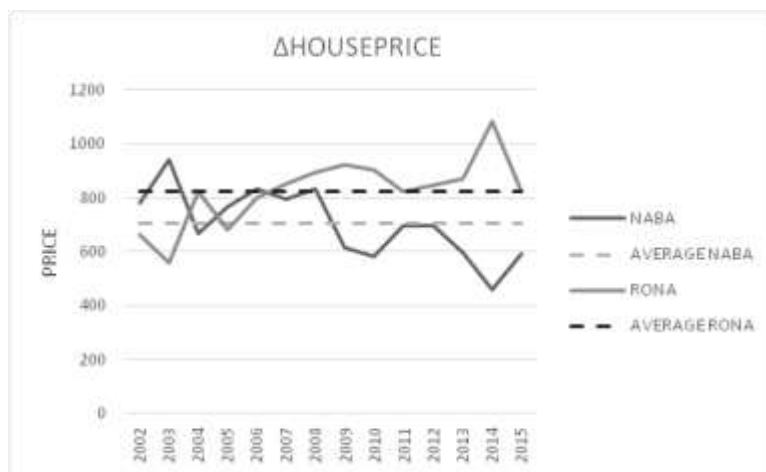
$\Delta HousePrice$  variable, this supports the result that between Milano and Turin a megalopolis does not exist and that the HSR has not had an effect on its formation.



Source: Authors 'elaborations based on Agenzia delle Entrate data

Figure 2 - MITO HSR corridors vs GEMI NON-HSR corridors -  $\Delta HousePrice$

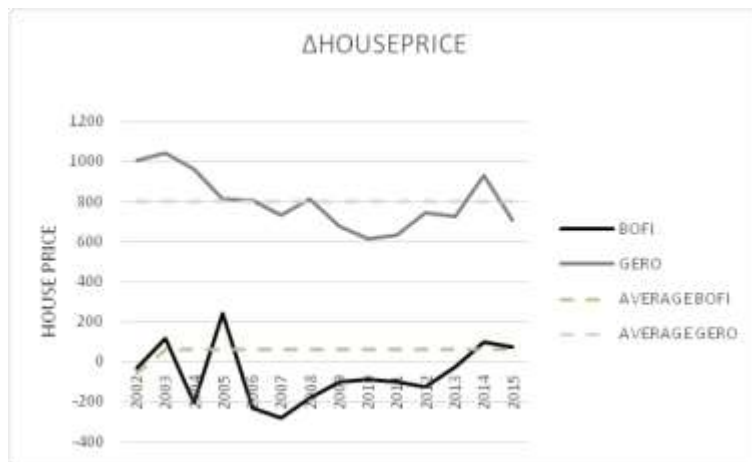
In Fig. 3 the variable  $\Delta HousePrice$ , analysed within the time period 2002-2015, for the RONA HSR corridor has been compared with the one of the NON-HSR NABA (NAPoli-Bari) corridor. Between the two, there is a difference since there is an increase in house prices for the RONA HSR corridor, but not for the NON-HSR NABA corridor.



Source: Authors 'elaborations based on Agenzia delle Entrate data

Figure 3 - RONA HSR corridors vs NABA NON-HSR corridors -  $\Delta HousePrice$

The BOFIRO HSR corridor has been compared with the NON HSR GERO (GENOVA-ROMA) corridor. Again, the results show that after the year 2009 the changes in both population and house prices for the two HSR corridors follow the same trend, therefore a megalopolis between Bologna, Firenze and Roma has not been fostered by HSR (see Fig. 4 and 5).



Source: Authors 'elaborations based on Agenzia delle Entrate data

Figure 4 - BOFI HSR corridors vs GERO NON-HSR corridors -  $\Delta HousePrice$



Source: Authors 'elaborations based on Agenzia delle Entrate data

Figure 5 - FIRO HSR corridors vs GERO NON-HSR corridors -  $\Delta HousePrice$

Further research will consider other potential corridors, which may be chosen as empirical case studies in order to model the effects of HSR in the creation of megalopolises. Among them Paris-Lyon in France; Frankfurt-Cologne in Germany; Madrid-Seville in Spain; Paris-Lille-Brussels between France and Belgium and London-Paris and London-Brussels between the UK, France and Belgium.

It is interesting to highlight the policy implications of this manuscript. HSR links may be definitely used to shape the direction of megalopolises within a new corridor through policies and decisions on operations (e.g., frequency, number of stops), intermodal linkages, station locations, etc...Another question concerns the need to reduce social exclusion. Indeed, HSR systems decrease the geographical exclusion by connecting cities previously far away (Pagliara and Biggiero, 2017).

Moreover, it is interesting to raise another important issue, i.e. megalopolises present the need for planning on a new spatial scale with new boundaries and linkages. This implies institutional change, for example the election of the new mayor of the newly formed megalopolis. Authors think that this is a topic to start talking about.

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